OPTIMAL WORK CONDITIONS DETERMINATION FOR DKUL 50-1 STEAM TURBINE

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Objectives: This paper wants to find the optimum in-energy transformation along steam turbine, to obtain (at electrical generator, also, at steam outlets of turbine) electrical and thermal quantities, as well as production costs of that energy to be chipper. In same time with mathematical process, the calculating program will generate a 3D graph who can give information's about turbine working point.

Methods: This study will be made on a back-pressure steam turbine type DSL 50-1, with a single constant flow extraction port for thermal medium pressure installations and five constant pressure extraction ports, for regenerating heating. For study we create a program who generate different sets of parameters of steam at turbine input and calculate results parameters of steam at extraction ports and also along the turbine, calculate the energy drops along the turbine and parameters of steam on the steam turbine exit.

Results: Based on the inputs and outputs energy quotations, mathematical application can generate a 3D image about energy transformation process, and can indicate the optimum working zone and characteristic parameters of that. Program will generate entire possible steam turbine work field and place the turbine work zone on it.

Conclusions: 3D image processes analyzing is more suggestive that a array of numbers into a table and can make more easy to take a decision about a characteristic of a working zone placed into good limited work field. The 3D-process image can be a good solution to have another point of view about thermoenergetic processes developed along the steam turbine.

Keywords: optimization, turbine, counter-pressure, staring mash, adjustable mash, mathematical simulation, marking.

1. Introduction

The DKUL 50-1 steam turbine is an action turbine, the counter-pressure type, in two assemblies, on one axle line, with a mean pressure adjustable mash, for industrial consumers steam supply, as well as for direct entrainment, through a semi-rigid coupler, of a alternating current generator. The turbine has also a

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number of five staring mashes for the recuperative preheating installation steam alimentation and a quasi-adjustable mash for additional steam extraction.

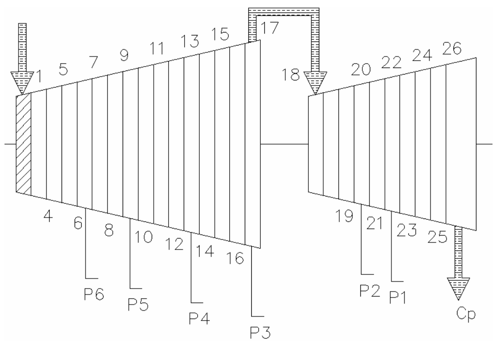

Fig. 1 DKUL 50-1Counter-pressure steam turbine

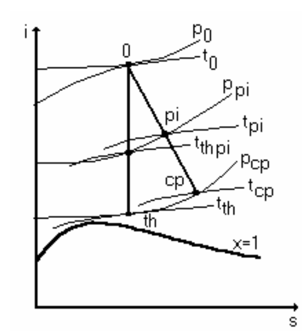

Fig.2 i-s diagram for the running cycle of a counter-pressure turbine with an adjustable mash.

The detent of the steam inside of the turbine assembly that is schematically showed in figure 1, will have a theoretic rate, (in i-s diagram) kindred with the one showed in figure 2. The electric and thermic energies distribution on the turbine is represented by an energetic distribution diagram, fig. 3. Each component of the energetic chain will have two different energetic under-components:

- an electric component;
- a thermic component.

Table 1

Section	Flow rate [t/h]	Pressure [ata]	Temperature [˚C]	Step
Live steam inlet	0 – 368 D_n = 320	130	545	0
Mash 6 – quasi-adjustable mash	40 – 50	70		6
Mash 5 – Recuperative mash	0,117 D_0			9
Mash 4 – Recuperative mash	0,0895 D_0			13
Mash 3 – Industrial mash	0 – 230 D_n = 115	10 – 18	280	17
Mash 2 – Recuperative mash	0,0221 D_0			20
Mash 1 – Recuperative mash	0,1897 D_0			22
Counter-pressure	D_n = 103 D_{gol} = 23 D_{min} = 20	0,7 – 2,5	164	26

The analysis, like in the case of a study on a simplified model, will focus on the study of this structure in search of the optime repartition of the two energies on the turbine.

W_0 will be considered the total power availability, or the total live steam power available at the turbine entrance, this power will be distributed in the seven principal components:

W_6 – the total equivalent power obtained at the quasi-adjustable mash,
W_5 – the total equivalent power obtained at the preheating mash nr. 5,
W_4 – the total equivalent power obtained at the preheating mash nr. 4,
W_3 – the total equivalent power obtained at the industrial mash,
W_2 – the total equivalent power obtained at the preheating mash nr. 2,
W_1 – the total equivalent power obtained at the district heating mash nr. 1,
W_{cp}– the total equivalent power obtained at counter-pressure.

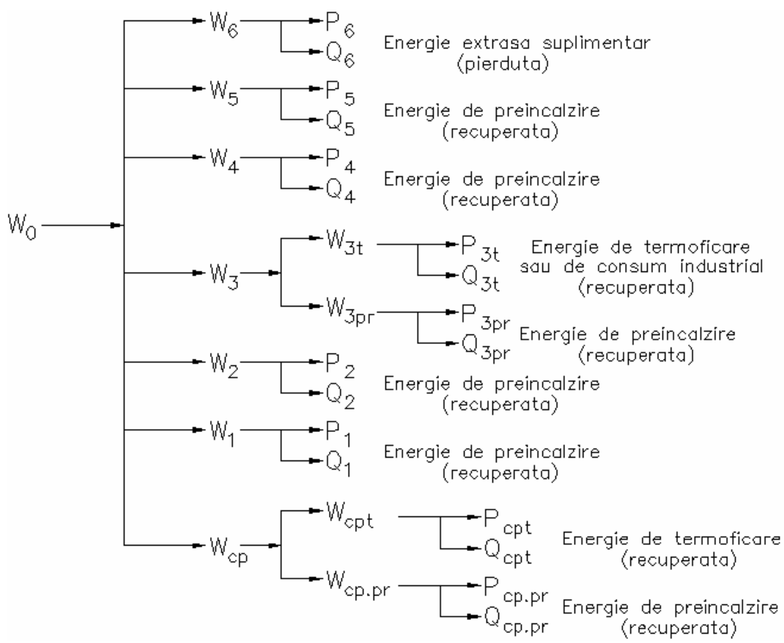

Fig. 3 The total power availability distribution for a DKUL 50-1turbine.

The total power availability will be:

$$W_0 = W_6 + W_5 + W_4 + \mathrm{W}_3 + \mathrm{W}_2 + \mathrm{W}_1 + \mathrm{W}_{cp} \ [kW] \qquad (1)$$

because the industrial steam extraction and the counter-pressure provides steam for the district heating, as well as for the recuperative preheating, W_3 and W_{cp} will have each two under-components:

$$W_3 = W_{3t} + W_{3pr} \quad [\mathrm{kW}]$$
$$\mathrm{W_{cp}} = W_{cpt} + W_{cp.pr} \quad [\mathrm{kW}] \qquad (1')$$

Developing the relation (1), we obtain a relation like:

$$W_0 = W_6 + W_5 + W_4 + \mathrm{W_{3t}} + W_{3pr} + \mathrm{W_2} + \mathrm{W_1} + \mathrm{W_{cpt}} + \mathrm{W_{cp.pr}}\ [kW] \qquad (1'')$$

The total equivalent power at the preheating mash:

$$W_i = \sum P_i + \sum Q_i\ [kW] \qquad (2)$$

were i=5, 3_{pr}, 2, 1, cp_{pr}

The total equivalent power at the quasi- adjustable mash:

$$W_6 = P_6 + Q_6\ [\mathrm{kW}] \qquad (3)$$

The total equivalent power at the industrial mash:

$$W_3 = P_{3t} + Q_{3t}\ [\mathrm{kW}] \qquad (4)$$

The total equivalent power at the counter-pressure:

$$W_{cp} = P_{cp} + Q_{cp}\ [kW] \qquad (5)$$

Developing the relations (2 – 5) will obtain:

- the electric power produced by the expansion of the steam flow rates used in the recuperative preheating installations:

$$P_i = \eta_m \cdot \sum D_i \cdot (h_0 - h_i)\ [kW] \qquad (6)$$

were i=5, 3_{pr}, 2, 1, cp_{pr}

- the total quantity of heat which exits the turbine through the turbine staring mashes and the quotas of heat extracted from the adjustable mash and from the counter-pressure used for the recuperative preheating:

$$Q^{\max}{}_i = \sum D_i \cdot h_i\ [kW] \qquad (7)$$

were i=5, 3_{pr}, 2, 1, cp_{pr}

- the effective heat quantity, Q_i , extracted through the turbine staring mashes and the quotas of heat extracted from the adjustable mash and counter-pressure, which are recuperated in the recuperative preheating installation:

$$Q_i = \sum D_i \cdot \left(h_i - h^i_{sat}\right)\ [\mathrm{kW}] \qquad (7')$$

were i=5, 3_{pr}, 2, 1, cp_{pr}

- the electric power produced by the expansion of the steam flow rate extracted from the quasi-adjustable mash:

$$P_6 = \eta_m \cdot \sum D_6 \cdot (h_0 - h_6)\ [kW] \qquad (8)$$

- the total heat quantity which exits the turbine through the quasi-adjustable mash:

$$Q^{\max}{}_6 = \sum D_6 \cdot h_6\ [kW] \qquad (9)$$

- the effective heat quantity, Q_6, extracted through the turbine adjustable mash

$$Q_6 = \sum D_6 \cdot \left(h_6 - h^6_{sat}\right)\ [\mathrm{kW}] \qquad (9')$$

- the electric power produced by the expansion of the steam flow rate extracted from the mean pressure mash (industrial mash), used in other proposes then the recuperative preheating:

$$P_{3t} = \eta_m \cdot D_{3t} \cdot (h_0 - h_t) \ [kW] \quad (10)$$

- the quantity of heat that exits the turbine through the adjustable mash, excepting the quantity of heat used in the recuperative preheating installations:

$$Q^{\max}{}_{3t} = D_{3t} \cdot h_{3t} \ [kW] \quad (11)$$

- the quantity of heat that is recuperated at the industrial consumers or in the top central heating installations, from $Q^{max}{}_{3t}$:

$$Q_{3t} = D_{3t} \cdot (h_{3t} - h_{sat}^{3t}) \ [\mathrm{kW}] \quad (11')$$

- the electrical power produced by the expansion of the steam flow rate which gets to the counter-pressure, used in the base central heating installations:

$$P_{cp.t} = \eta_m \cdot D_{cp.t} \cdot (h_0 - h_{cp}) \ [kW] \quad (12)$$

- the absolute quantity of heat that exits the turbine at counter-pressure, used in the base central heating installations:

$$Q^{\max}{}_{cp.t} = D_{cp.t} \cdot h_{cp} \ [kW] \quad (13)$$

- the quantity of heat, from $Q^{max}{}_{cp.t}$, transferred to the thermic agent in the base central heating installations:

$$Q_{cp.t} = D_{cp.t} \cdot (h_{cp} - h_{sat}^{cp}) \ [\mathrm{kW}] \quad (14')$$

were:

D_0 – live steam flow rate *[kg/s]*
D_6 – the steam flow rate extracted at the quasi-adjustable mash *[kg/s]*
D_5, D_2, D_1 – the steam flow rate extracted at the staring mashes *[kg/s]*
D_3 – the steam flow rate extracted at the industrial mash used in the top central heating installation, or at the industrial steam consumers *[kg/s]*
D_{3pr} – the steam quota extracted at the industrial mash used at the recuperative preheating installations *[kg/s]*
D_{cpt} – the steam flow rate that exits from the turbine at counter-pressure, used in base central heating installations *[kg/s]*
$D_{cp.pr}$ – the steam flow rate that exits from the turbine at counter-pressure, used in the recuperative preheating installations *[kg/s]*
h_0 – the live steam enthalpy *[kJ/kg]*
h_6 – the steam enthalpy at the quasi-adjustable mash *[kJ/kg]*
h_5, h_2, h_1 – the steam enthalpy for the staring mashes *[kJ/kg]*
h_3 – the steam enthalpy at the adjustable (industrial) mash *[kJ/kg]*
h_{cp} – the steam enthalpy at counter-pressure *[kJ/kg]*
$h^x{}_{sat}$ – the saturation enthalpy of the steam *[kJ/kg]*
η_m – the mechanic efficiency of the turbine *[%]*

It can be seen that, for a constant live steam flow rate, at the entrance of the turbine, we will obtain:

- a total electric an thermic power, developed by the steam flow rate extracted from the staring mashes with a almost constant value, in case that the pressure at the staring mashes does not fluctuate to much with the fluctuation of the steam flow rate through the turbine (if $h_i \approx ct.$), because $D_i = kD_0$ with $k = ct.$;
- a total electric an thermic power, developed by the steam flow rate extracted from the quasi-adjustable mash, directly proportional with same;
- a variable, total electric an thermic power, developed by the steam flow rate used for the industrial consume and for the top central heating installations, extracted at the adjustable mash, directly proportional with this flow rate;
- an electric power developed by the steam flow rate that travels through the entire turbine and gets at counter-pressure, directly proportional with the flow rate and a thermic power used in the base central heating installations.
- The relations (1) – (14') represent the mathematical model of the thermoenergetic transformations along the turbine, from the inlet to the exhaust in counter-pressure. The tabbing and graphic representation of the results leads to the realization of a tridimensional running graph for the turbine similar to the one presented in figure 4, 5. The graphic representation presented was realized for null flow rates at the quasi-adjustable mash of the turbine, conditions that are accomplished by the turbines which fit up CET Progresu – Bucharest, were that mash is iron-cased. In case that the fluctuations of the flow rate of the quasi-adjustable mash have to be tacked into account, the DKUL 50-1 turbine will be necessary to be treated, from the described optimisation principles point of view, like a turbine with two adjustable mashes.

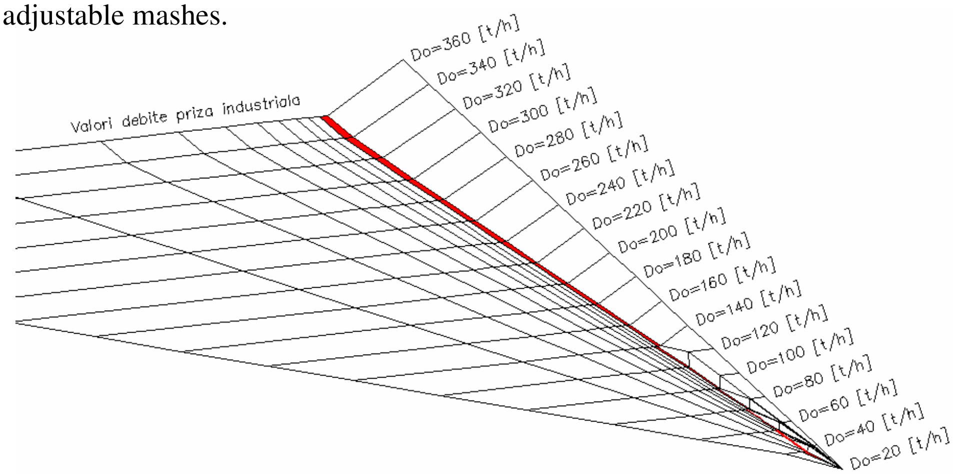

Fig. 4 Images of the optimization function graph for the DKUL 50-1 (Do=20 - 360 t/h, p_{ind}=13 bar, p_{cp}=1,2 bar) turbine

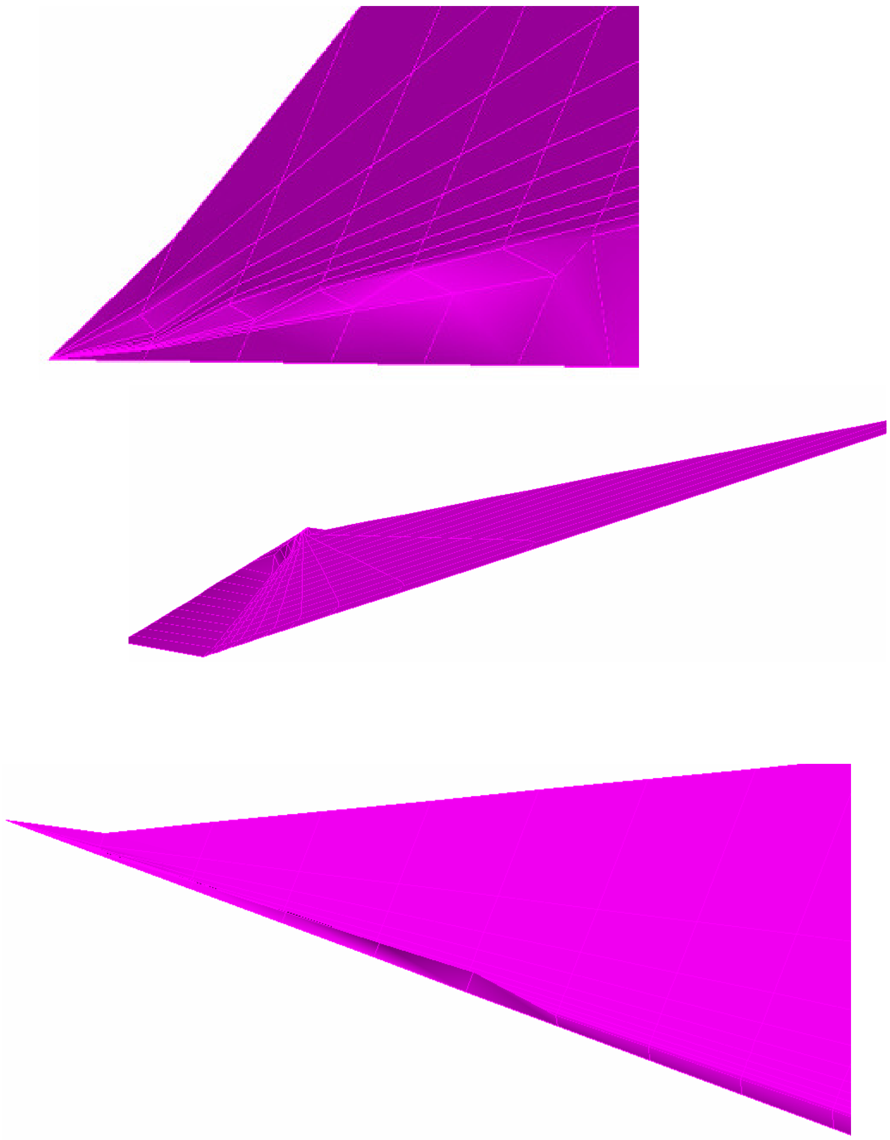

Fig. 5 Images of the rended optimization function graph for the DKUL 50-1 (Do=20 - 360 t/h, p_{ind}=13 bar, p_{cp}=1,2 bar) turbine

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